J. Soils and Crops 33 (1) 162-167, June 2023

ISSN 0971-2836 (Print)
ISSN 2582-2756 (Online)

HETEROBELTIOSIS AND USEFUL HETEROSIS STUDIES IN DIFFERENT SPECIES OF MUSTARD (*Brassica* Sp.)

Vasundhara A. Chaudhari[1], Sandeep R. Kamdi[2], Shivam Barde[3] and Jyoti G. Shinde[4]

ABSTRACT

Heterosis was estimated in Indian mustard for 12 quantitative characters. Eighteen F1 crosses were obtained by line × tester mating design using 6 lines and 3 testers. These eighteen crosses along with parents (TAM 108-1 and Kranti used as parent as well as check) were grown at AICRP on linseed and mustard experimental farm, College of Agriculture, Nagpur during 2021-22 in randomized block design with three replications. The crosses Bio-902 × *Synapsis alba*, Bio-902 × PC-6, ACN 9 × Chhattisgarh Sarson, PM-26 × Chhattisgarh Sarson and Kranti × Chhattisgarh Sarson had high mean performance and exhibited significant useful heterosis over the superior check for yield and most of its contributing characters *viz.,* days to maturity, number of branches plant^{-1}, number of siliquae plant^{-1}, siliquae density on main branch, oil content, number of seeds siliqua^{-1}, 1000 seed weight, point to first siliqua, siliqua length, days to 50 % flowering. These crosses identified as superior crosses, which can be utilized for development of hybrid varieties.

(Key words: Mustard, Heterosis, useful heterosis, Heterobeltiosis, Yield)

INTRODUCTION

Agriculture sector plays a significant role in India's social security and overall economic welfare. It is the basic foundation of economic development. Oilseeds occupy significant place in Indian economy next to food grain. India is the third largest producer of oilseeds in the world. Mustard is the second most important oilseed crop in India after soybean. It accounts for nearly 20-22% of the total oilseeds produced in the country (Anonymous, 2021).Indian mustard [*Brassica juncea* (L.) Czern and Cross] is an important oilseed crop of the world. It is popularly known as rai, raya or laha in India. Indian mustard belongs to family Cruciferae (*syn. Brassicaceae*) and genus *Brassica*. Indian mustard is a natural amphidiploid (AABB, 2n=36) of *Brassica rapa* (2n=20) and *Brassica nigra* (2n=16) (Nagaheru, 1935). It originated in Asia with its major center of diversity in China. It was introduced in India from China and from where it spread to Afghanistan and other countries. It is largely a self-pollinated crop (85-90%). However, owing to insects, especially the honeybees, the extent of cross-pollination varies from 5-18%. (Labana and Banga, 1984).

Mustard is minor crop of Eastern Vidarbha region, farmers are growing mustard crop in last week of November to second week of December after harvesting of paddy. Generally delayed planting leads to shortening of vegetative phase, advances flowering time and decreases seed development period resulting into shrivelled seed. Similarly, incidence of powdery mildew occurs at flowering and siliqua development stage therefore, farmers receive very poor yield (1-2 q acre^{-1}). There is need of producing high yielding varieties with early maturity, high oil content and powdery mildew resistance varieties which will be perform better in terminal heat shock. Heterosis study provides information about probable gene action and help in sorting out desirable crosses. Heterosis breeding can be one of the most viable option for breaking the yield barrier. (Allard, 1960).

MATERIALS AND METHODS

The experimental material consisted 6 lines *viz*., TAM 108-1, ACN 9, Kranti, PM-26, Bio-902, and PM-28 and 3 testers *viz.,* Chhattisgarh Sarson, PC-6 and *Synapsis alba* which were crossed in line x tester fashion during the year 2020-21 in *rabi* season. The crosses along with their parents were planted in randomized block design in three replications at Research field of AICRP (Linseed and Mustard), College of Agriculture, Nagpur in *rabi* 2021-22. Each genotype was grown in two rows with spacing 45×15 cm^2 for row to row and plant to plant respectively. Where, length of each row was 2 m and 5 plants were used for observation. Observations were recorded on 12 quantitative characters *viz.,* days to 50% flowering, days to maturity, plant height, number of branches plant^{-1}, point to first siliqua, siliqua length, number of seeds siliqua^{-1}, number of siliquae plant^{-1}, siliquae density on main branch, 1000 seed weight, seed yield plant^{-1} and oil content. All recommended agronomical practices were followed to raise healthy crop. The analysis of variance were performed to test the significance of difference between

1, 3 and 4. P.G. Student, Agricultural Botany Section, College of Agriculture, Nagpur
2. Mustard Breeder, AICRP on Linseed and Mustard, College of Agriculture, Nagpur

the genotypes for all the characters as the methodology suggested by Panse and Sukhatme (1954). The hybrid performance (%) tested in comparison with better parent (heterobeltiosis) and check (useful heterosis) was calculated as per the formulae given by Fonseca and Patterson (1968) and Meredith and Bridge (1972) respectively.

RESULTS AND DISCUSSION

The data regarding analysis of variance for heterosis are presented in Table 1. The analysis of variance for heterosis was estimated for days to 50% flowering, days to maturity, plant height (cm), number of branches plant^{-1}, point to first siliqua (cm), siliqua length (cm), number of seeds sliqua^{-1}, number of siliquae plant^{-1}, siliquae density on main branch, 1000 seed weight (g), seed yield plant^{-1} (g) and oil content (%). Mean square due to parents were found to be highly significant for all the characters. This express the presence of significant variability among the parents. Significant mean square for crosses were recorded for all twelve characters. Data revealed significant difference among the crosses. The mean square due to interaction effects of parents *vs*. crosses were found to be significant for all characters except plant height and point to first siliqua. The presence of significant difference among parents and crosses revealed the choice of exploiting heterosis for the above characters.

Among the 18 crosses, six crosses exhibited desired negative significant heterobeltiosis for days to 50% flowering in which cross Kranti × PC-6 (-21.14%) had highest negative significant heterobeltiosis. Whereas, useful heterosis over best check Kranti found in cross PM-28 × Chhattisgarh Sarson (-8.21%). For the days to maturity negative significance is desirable. Four cross combinations found negative significant heterobeltiosis for days to maturity in which highest negative significant heterobeltiosis was observed in ACN 9 × PC-6 (-14.20%). Negative significant useful heterosis over best check Kranti was observed in ACN 9 × PC -6 (-6.21%). Positive significance is desirable for plant height but none of the cross combinations showed positive significant heterobeltiosis as well as useful heterosis for plant height. Seven crosses showed desired positive significant heterobeltiosis for number of branches plant^{-1} in which highest magnitude of positive significant heterobeltiosis was recorded by Bio-902 ×*Synapsis alba* (-90.96%). While eight crosses showed positive significant useful heterosis over best check TAM 108-1 for number of branches plant^{-1}. Point to first siliqua is also the trait where, negative significant heterobeltiosis is desirable. Among 18 crosses two were found to be negative significant heterobeltiosis and four crosses showed negative significant useful heterosis over best check TAM 108-1 in which hybrid PM-28 × *Synapsis alba* (-21.97%) had maximum negative useful heterosis. Eight cross combinations reported negative significant heterobeltiosis for siliqua length and one cross ACN 9 × Chhattisgarh Sarson (13.58%) had positive significant heterobeltiosis. Among the 18 crosses, four crosses exhibited negative significant useful heterosis and two crosses showed positive significant useful heterosis over best check TAM 108-1. Highly significant positive useful heterosis was reported by hybrid PM-28 × *Synapsis alba* (19.96%). Ten crosses exhibited negative significant heterobeltiosis and none of the crosses exhibited positive significant heterobeltiosis for trait number of seeds siliqua^{-1} while, two crosses showed significant useful heterosis over the best check TAM 108-1 of which One cross was negatively significant PM-26 × PC-6 (-72.37%) and another one was ACN 9 × Chhattisgarh Sarson (21.04%) was positively significant. For number of siliquae plant^{-1}, seven crosses showed positive significant heterobeltiosis in which maximum positive significant heterobeltiosis was recorded by PM-26 × PC-6 (307.33%). Again seven cross combinations were found positively significant for useful heterosis over best check Kranti in which highest magnitude of positive useful heterosis observed in cross PM-26 × PC-6 (244.51%). Four crosses showed the significant heterobeltiosis of which two crosses showed negative significant heterobeltiosis and three crosses showed positive significant heterobeltiosis for siliquae density on main branch. The cross Bio-902 × *Synapsis alba* (22.49%) exhibited highest significant positive heterobeltiosis. Five crosses found significant useful heterosis over the best check TAM 108-1, of which three crosses showed negative useful heterosis and two showed positive useful heterosis, highest positive useful heterosis observed in PM-26 ×Chhattisgarh Sarson (23.60%). Seven crosses found negatively significant and six crosses found positively significant for the character 1000 seed weight. Eleven crosses recorded negative significant useful heterosis and four positive significant useful heterosis, in which cross combination Kranti × Chhattisgarh Sarson (9.62%) had highest positive usefulheterosis. For the character seed yield plant^{-1}, nine crosses exhibited significant positive heterobeltiosis and maximum positive significant heterobeltiosis recorded in Bio-902 × *Synapsis alba* (100.55%). Eleven crosses reported as positive significant useful heterosis over best check TAM 108-1 in which hybrid Bio-902 × *Synapsis alba* (161.80%) recorded highest positive significant useful heterosis. For oil content four crosses exhibited positive significant heterobeltiosis and cross Kranti × Chhattisgarh Sarson (19.45%) recorded highest positive significant heterobeltiosis. Six crosses showed significant useful heterosis over best check TAM 108-1 from which four crosses exhibited positive useful heterosis and two crosses exhibited negative useful heterosis. Significant positive heterosis for seed yield plant^{-1} in mustard in their study were observed by earlier workers Barupal *et al.* (2017), Nair *et al.* (2018), Deshmukh *et al.* (2021) and Sapkal *et al.* (2021).

On the basis of high mean performance and significant useful heterosis in desirable direction, the potential crosses were identified for explotation are listed in Table 5. The cross Bio-902 × *Synapsis alba* found best cross followed by Bio-902 × PC-6, ACN 9 × Chhattisgarh

Table 1. Analysis of variance for heterosis

Sources of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches plant^{-1}	Point to first siliqua (cm)	Siliqua length (cm)	Number of seeds siliqua^{-1}	Number of siliquae plant^{-1}	Siliqaue density on main branch	1000 seed weight (g)	Seed yield plant^{-1} (g)	Oil content (%)
		Mean squares											
Replicatios	2	7.87	19.64	554.21	0.01	103.57	0.27	2.78	925.64	0.005	0.09	11.87	6.81
Genotypes	26	57.05**	147.41**	2933.59**	1.97**	510.78**	1.75**	51.02**	82388.31**	0.08**	1.63**	135.62**	26.83**
Parents	8	88.46**	71.67**	5597.38**	0.57**	887.29**	2.25**	114.08**	29082.71**	0.10**	1.39**	41.53**	16.69**
Crosses	17	44.36**	182.78**	1789.71**	2.44**	350.97**	1.47**	19.41**	96370.16**	0.07**	1.78**	138.59**	31.63**
Parents *vs* Crosses	1	21.49*	152.15**	1069.17	5.26**	215.49	2.39**	83.70**	271141.66**	0.16**	1.02**	939.66**	26.34**
Error	52	3.92	10.83	315.95	0.04	103.47	0.10	1.60	1211.55	0.005	0.04	4.36	3.27

Table 2. H1-Heterobeltiosis, H2 (1) and H2 (2) – Useful Heterosis over TAM 108-1 and Kranti

Crosses	Days to 50% flowering			Days to maturity			Plant height (cm)			No of branches plant^{-1}		
	H1	**H2 (1)**	**H2 (2)**	**H1**	**H2 (1)**	**H2 (2)**	**H1**	**H2 (1)**	**H2 (2)**	**H1**	**H2 (1)**	**H2 (2)**
TAM 108-1 X												
Chhattisgarh Sarson	-6.04	-6.04	4.48	-5.34*	-1.54	-0.93	-11.44	-11.44	-3.03	-15.98**	-9.80	-8.00
TAM 108-1 X PC-6	-15.43**	-0.67	10.45**	2.56	11.42**	12.11**	-13.61	-13.61	-5.41	-0.98*	-0.98	1.00
TAM 108-1 X *Synapsis alba*	-2.01	-2.01	8.96*	4.32	4.32	4.97	-6.95	-6.95	1.89	13.73*	13.73*	16.00**
ACN 9 X Chhattisgarh Sarson	0.71	-5.37	5.22	-4.15	-0.31	0.31	-8.88	-14.50	-6.38	7.79	20.69**	23.10**
ACN 9 X PC-6	-3.43	13.42**	26.12**	-14.20**	-6.79	-6.21**	12.97	-6.74	2.12	20.84**	35.29**	38.00**
ACN 9 X *Synapsis alba*	15.75**	-1.34	9.70**	1.93	-2.16	-1.55	-27.30**	-39.98**	-34.28**	-19.88**	-10.29	-8.50
Kranti X Chhattisgarh Sarson	-1.43	-7.38*	2.99	-2.97	0.93	1.55	-9.12	-14.73	-6.63	11.42*	19.61**	22.00**
Kranti X PC-6	-21.14**	17.45**	2.99	5.97*	8.64**	15.84**	2.60	-8.67	2.60	-5.80	-1.96	-5.80
Kranti X *Synapsis alba*	-1.49	-11.41**	-1.49	1.24	0.62	1.24	-7.41	-15.44*	-7.41	-3.50	-5.39	-3.50
PM-26 X Chhattisgarh sarson	-4.29	-10.07**	0.00	-8.01**	-4.32	-3.73	-3.04	-7.79	0.96	-18.64**	-5.88	-4.00
PM-26 X PC-6	-12.00**	3.36	14.93**	7.67**	16.98**	17.70**	4.65	-0.48	8.97	59.49**	84.51**	88.20**
PM-26 X *Synapsis alba*	-4.55	-15.44**	-5.97	-3.34	-1.85	-1.24	-27.08**	-30.66**	-24.07**	-12.54**	1.18	3.20
Bio-902 X Chhattisgarh Sarson	2.86	-3.36	7.46*	-1.19	2.78	3.42	3.01	-2.50	6.75	-11.69**	-5.20	-3.30
Bio-902 X PC-6	-14.29**	0.67	11.94**	4.55	13.58**	14.29**	2.44	-3.04	6.16	40.91**	21.57**	24.00**
Bio-902 X *Synapsis alba*	-4.29	-10.07**	0.00	0.95	-1.54	-0.93	-0.62	-5.94	3.00	90.96**	65.69**	69.00**
PM-28 X Chhattisgarh Sarson	-12.14**	-17.45**	-8.21*	-8.90**	-5.25*	-4.66	-0.97	-7.08	1.74	-5.02	1.96	4.00
PM-28 X PC-6	-12.00**	3.36	14.93**	-4.26	4.01	4.66	-6.08	-25.13**	-18.02*	37.16**	18.33**	20.70**
PM-28 X *Synapsis alba*	2.42	-14.77**	-5.22	1.62	-3.09	-2.48	-18.97	-41.67**	-36.13	8.47	-5.88	-4.00
SE (d)	**1.62**	**1.62**	**1.62**	**2.68**	**2.68**	**2.68**	**14.51**	**14.51**	**14.51**	**0.18**	**0.18**	**0.18**

** = Significant at 1% level * = Significant at 5% level

Table3. H1-Heterobeltiosis, H2 (1) and H2 (2) – Useful Heterosis over TAM 108-1 and Kranti respectively

Crosses	Days to 50% flowering			Days to maturity			Plant height (cm)			No of branches plant^{-1}		
	H1	H2 (1)	H2 (2)	H1	H2 (1)	H2 (2)	H1	H2 (1)	H2 (2)	H1	H2 (1)	H2 (2)
TAM 108-1 X Chhattisgarh Sarson	-6.17	-0.89	-14.77	9.04	9.04	10.95	-6.32	13.87	24.33*	7.51	23.68**	21.72*
TAM 108-1 X PC-6	13.72	17.21	0.80	4.93	4.93	6.77	2.61	2.61	12.03	14.70	14.70	12.88
TAM 108-1 X *Synapsis alba*	-5.16	-5.16	-18.44*	-41.17	-13.60*	-12.09	-59.71**	-1.25	7.82	16.91	16.91	15.06
ACN 9 X Chhattisgarh Sarson	-3.91	1.50	-12.71	13.58*	10.61	12.55*	-0.42	21.04**	32.16**	46.94**	69.04**	66.36**
ACN 9 X PC-6	-23.87**	-21.54*	-32.52**	-11.74	-14.05*	-12.55*	-18.67**	-13.11	-5.13	30.09**	24.32*	22.34*
ACN 9 X *Synapsis alba*	-11.18	-18.18*	-29.63**	-48.24**	-23.99**	-22.66**	-62.20**	-7.36	1.16	-13.73	-17.56	-18.86
Kranti X Chhattisgarh Sarson	-11.49	2.93	-11.49	2.36	0.60	2.36	-16.48*	1.52	10.85	-0.72	14.21	12.40
Kranti X PC-6	-18.04*	16.29	-18.04**	0.53	-1.72	0.53	-1.60	-8.41	-1.60	-14.51	1.61	-14.51
Kranti X *Synapsis alba*	-15.16	-1.34	-15.16	-40.10**	-12.03	-10.49	-61.35**	-5.27	3.44	0.24	1.85	0.24
PM-26 X Chhattisgarh sarson	-7.90	-2.71	-16.34*	6.32	6.50	8.37	-4.76	15.77	26.41**	-8.44	5.33	3.66
PM-26 X PC-6	3.07	6.24	-8.64	-44.49**	-44.39**	-43.42**	-70.70**	-72.37**	-69.83**	307.33**	250.06**	244.51**
PM-26 X *Synapsis alba*	-9.73	-17.43*	-28.99**	-19.64**	18.01**	20.08**	-60.91**	-4.18	4.62	-10.96	-23.48*	-24.69
Bio-902 X Chhattisgarh Sarson	4.89	10.79	-4.73	-3.84	-2.77	-1.06	-16.93*	0.98	10.25	26.77**	45.84**	43.53**
Bio-902 X PC-6	12.36	15.81	-0.41	-4.51	-3.44	-1.75	12.93	14.01	24.48*	25.15*	29.46**	27.41**
Bio-902 X *Synapsis alba*	2.08	2.19	-12.13	-34.35**	-3.59	-1.90	-62.29**	-7.57	0.92	31.50**	36.03**	33.87**
PM-28 X Chhattisgarh Sarson	-8.84	-3.71	-17.20*	-17.97**	8.15	10.04	-5.20	15.23	25.82**	4.32	20.01	18.11
PM-28 X PC-6	-8.77	-5.97	-19.14*	-16.95**	9.49	11.41	-13.24	-20.66	-13.37	51.25*	-20.42	-21.68
PM-28 X *Synapsis alba*	-5.82	-21.97*	-32.90*	-18.32**	19.96*	22.05**	-57.02**	5.35	15.03	-28.52	-64.26**	-64.83
SE (d)	**8.31**	**8.31**	**8.31**	**0.27**	**0.27**	**0.27**	**1.03**	**1.03**	**1.03**	**28.42**	**28.42**	**28.42**

** = Significant at 1% level * = Significant at 5% level

Table 4. H1-Heterobeltiosis, H2 (1) and H2 (2) – Useful Heterosis over TAM 108-1 and Kranti respectively

Crosses	Siliquae density on main branch			1000 seed weight (g)			Seed yield plant^{-1} (g)			Oil content (%)		
	H1	**H2 (1)**	**H2 (2)**	**H1**	**H2 (1)**	**H2 (2)**	**H1**	**H2 (1)**	**H2 (2)**	**H1**	**H2 (1)**	**H2 (2)**
TAM 108-1 X Chhattisgarh Sarson	-0.44	1.72	13.35	7.12*	7.12*	8.93*	-0.84	28.93*	46.07**	0.80	0.80	0.84
TAM 108-1 X PC-6	-13.20	-13.20	-3.27	-17.37**	-17.37**	-15.97**	67.92**	67.92**	90.25**	-2.41	4.26	4.31
TAM 108-1 X *Synapsis alba*	-3.80	-3.80	7.20	-19.68**	-19.68**	-18.32**	19.28	19.28	35.14*	-7.71	-7.71	-7.68
ACN 9 X Chhattisgarh Sarson	17.35*	19.89**	33.60**	9.77*	-15.00**	-13.56**	84.35**	139.70**	171.58**	-2.26	-4.49	-4.45
ACN 9 X PC-6	3.64	0.41	11.89	39.49**	8.01*	9.84**	2.53	30.05	47.34**	5.91	13.15**	13.19**
ACN 9 X *Synapsis alba*	-38.96**	-40.87**	-34.11**	5.55	-18.27**	-16.88**	14.94	45.79**	65.18**	-8.37	-10.47*	-10.43*
Kranti X Chhattisgarh Sarson	-1.33	0.81	12.34	11.47**	9.62**	11.47**	61.87**	110.47**	138.46**	19.45**	19.41**	19.45**
Kranti X PC-6	2.62	-10.26	2.62	1.04	-1.67	1.04	13.79	-11.74	13.79	0.35	6.84	7.25
Kranti X *Synapsis alba*	-2.12	-12.16	-2.12	-11.80**	-13.27**	-11.80**	22.68	8.28	22.68	-7.01	-7.05	-7.01
PM-26 X Chhattisgarh sarson	20.97*	23.60**	37.73**	-19.51**	-26.22**	-24.97**	65.79**	130.66**	161.32**	17.14**	12.21**	12.25**
PM-26 X PC-6	9.61	-3.57	7.46	-23.99**	-30.32**	-29.14**	-12.83	21.28	37.40*	-6.22	0.19	0.23
PM-26 X *Synapsis alba*	-37.84**	-50.77**	-45.14**	-18.32**	-25.13**	-23.86**	-1.95	36.41*	54.55**	5.61	1.16	1.20
Bio-902 X Chhattisgarh Sarson	13.23	15.69	28.92	2.72	4.23	6.00	36.99**	78.83**	102.61**	1.64	-3.30	-3.26
Bio-902 X PC-6	-0.98	-12.88	-2.92	7.52*	9.10*	10.95**	90.65**	148.89**	181.98**	-10.89**	-4.79	-4.76
Bio-902 X *Synapsis alba*	22.49**	-0.05	11.39	-23.44**	-22.31**	-20.99**	100.55**	161.80**	196.61**	13.19**	2.78	2.82
PM-28 X Chhattisgarh Sarson	7.70	10.04	22.62*	32.44**	4.94	6.71	25.18*	62.76**	84.41**	8.62*	20.14**	20.19**
PM-28 X PC-6	5.14	-7.50	3.07	8.33	-14.17**	-12.71**	26.05	-10.83	1.03	-6.68	3.22	3.26
PM-28 X *Synapsis alba*	-11.70	-44.39**	-38.04**	-15.86	-33.33**	-32.20**	67.33**	24.29	40.82*	-18.75**	-10.13*	-10.09*
SE (d)	**0.06**	**0.06**	**0.06**	**0.18**	**0.18**	**0.18**	**1.75**	**1.70**	**1.70**	**1.48**	**1.48**	**1.48**

****= Significant at 1 % level *= Significant at 5% level**

Table 5. Crosses selected for heterosis breeding on the basis mean performance, useful heterosis and SCA effect of crosses for yield and other characters

Sr. No.	Crosses	Mean	Useful heterosis	Heterosis superior over best check	Significant superior performance over best check
1	Bio-902 X *Synapsis alba*	31.83	161.80**	NOB, NOS, OC	NOB, NOS
2	Bio-902 X PC-6	30.26	148.89**	NOB, NOS, 1000SW, OC	NOB, NOS, 1000SW
3	ACN 9 X Chhattisgarh Sarson	29.14	139.70**	NOB, ,NOSPS, NOS, SD, OC	NOB, NOSPS, NOS, SD
4	PM-26 X Chhattisgarh Sarson	28.04	130.66**	SD, OC	SD, OC
5	Kranti X Chhattisgarh Sarson	25.59	110.47**	NOB, 1000SW, OC	NOB, 1000SW, OC

Note: DTM = Days to maturity (days), NOB = Number of branches, NOS = Number of siliquae plant^{-1}, SD = Siliquae density on main branch,OC = Oil content (%), NOSPS = Number of seeds siliqua^{-1},DT50%F = Days to 50% flowering , P to 1stS = Point to first siliqua (cm), Yield = Seed yield plant^{-1} (g), 1000SW = 1000 seed weight (g), SL = Siliqua length (cm)

Sarson, PM-26 × Chhattisgarh Sarson and Kranti × Chhattisgarh Sarson for seed yield and its contributing characters, hence could be evaluated further to exploit the heterosis and utilized in future breeding programmes to obtain desirable and superior genotypes. The identification of crosses on the basis of high mean performance and significant useful heterosis was also done by Meena *et al.* (2015), Patel *et al.* (2015), Deshmukh *et al.* (2021) and Raut *et al.* (2021) in mustard.

REFERENCES

Allard, R. W. 1960. Principles of plant breeding. New York. John wily and sons.

Anonymous, 2021. Agricultural Statistics at glance. (www.mahaagri.gov.in)

Barupal, H. L., A. K. Sharma, H. V. S. Shekhavat, P. Kumar and M. Kumar, 2017. Heterosis studies in mustard [*Brassica juncea*]. Int. J. Agri. Innov. & Res. **5**(6): 2319-1473.

Deshmukh, A. S., S. R. Kamdi, B. Nair, S. R. Patil, S. S. Bhure and H. P. Ingole, 2021. Heterosis for seed and yield contributing characters in mustard (*Brassica* species). J. Soils and Crops. **31**(2): 371-376.

Fonseca, S. and F. L. Patterson, 1968. Hybrid vigour in a seven parents diallel crosses in common winter wheat (*Triticum aestivum* L.). Crop Sci. **8**: 85-88.

Labana, K. S., K. L. Ahuja, S. S. Banga, 1984. Evaluation of some Ethiopian mustard (*Brassica carinata*) genotypes under Indian conditions. Proceedings of the 7th International Rapeseed Congress. 115.

Meena, H. S., A. Kumar, B. Ram, V. V. Singh, P. D. Meena, B. K. Singh and D. Singh, 2015. Combining ability and heterosis for seed yield and its components in Indian mustard (*Brassica juncea* L.). J. Agric. Sci. Tech. **17**: 1861- 1871.

Meredith, W. R. and R. R. Bridge, 1972 Heterosis and gene action in cotton *G. hirsutum* (L.) Crop Sci. **12 :** 304-30.

Nair, B., S. A. Badge and D. D. Mankar, 2018. Heterosis for seed yield and its attributes in Indian mustard (*Brassica juncea*). J. Agric. Res. Technol. **43**(2): 248-253.

Nagaharu, U. 1935. Genome analysis in Brassica with special reference to the experimental formation of *B. napus* and peculiar mode of fertilization. Japan J. Bot. **7**: 389-452.

Panse, V. G. and P. V. Sukatme, 1954. Statistical methods for agricultural workers. ICAR. Publication, New Delhi. 2 pp. 63-66.

Raut, P. D., S. R. Kamdi, B. Nair, R. D. Deotale, A. D. Sapkal, S. S. Bhure, J. M. Prabhat and N. D. Dadas, 2021. Heterosis for seed yield and yield contributing characters in Indian mustard [*Brassica juncea* (L.)]. J. Soils and Crops. **31**(1): 105-109.

Sapkal, A. D., S. R. Kamdi, B. Nair, R. D. Deotale, P. D. Raut, S. S. Bhure and J. M. Prabhat, 2021. Heterosis for seed yield and yield contributing characters in Indian mustard [*Brassica juncea* (L.)]. J. Soils and Crops. **31**(1): 152-157.

Rec. on 25.11.2022 & Acc. on 08.12.2022